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ARPA Authoring System

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LEXINGTON, MASSACHUSETTS

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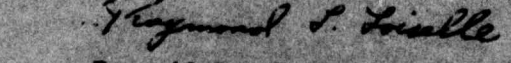
FOR THE COMMANDER



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ARPA AUTHORING SYSTEM

SEMIANNUAL TECHNICAL SUMMARY REPORT
TO THE
DEFENSE ADVANCED RESEARCH PROJECTS AGENCY

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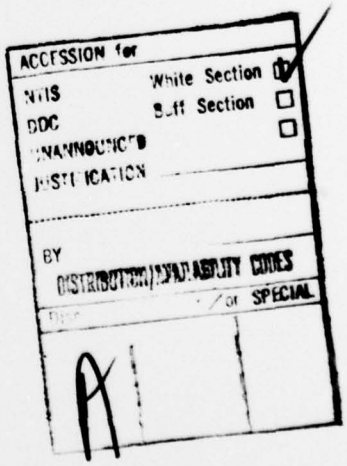
ABSTRACT

The need is established for using Subject Matter Experts as authors of materials for technical training for OJT. The activities and major findings as a result of authoring operations on-site are reviewed. The training system requirements established are described, and the rationale for using a procedural approach to authoring and task-related models for lesson designs is given. The necessity from a manager's view for OJT to improve work performance and for efficient use of experts as authors is emphasized. Examples of development of two task-related lessons are presented, and the plan for a test of lesson products is discussed briefly.



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ARPA AUTHORING SYSTEM

I. INTRODUCTION

A. Problem Statement

The goal of this project is to design, deploy, field test, and evaluate a system to enable local, qualified personnel to prepare individualized instructional material for on-the-job training (OJT) by machine delivery. OJT is the only appropriate type of training for most operational, maintenance, and repair tasks because these tasks are unique to particular pieces of equipment and to the environment in which the equipment is used.

Currently, OJT is conducted by qualified operators and technicians who instruct and supervise novice personnel, most frequently on a one-to-one basis. These same operators and technicians are also responsible for equipment maintenance, repair, readiness, and operations. As a consequence, training is often unavailable and, at best, inefficient. Capturing the expertise of these technicians and operators in suitable form for automated delivery could provide continuous availability of training, decrease the demand for expert personnel to conduct one-to-one instruction, further standardize training, and increase the overall effectiveness of OJT.

While the feasibility of machine delivery of instruction at the work site has been demonstrated with the Lincoln Terminal System (LTS), the acquisition of appropriate instructional material remains a challenge. Professional technical instructors or writers are not suited to the task of generating such material because they seldom have the extensive local operational experience and up-to-date technical knowledge that are required to design materials with the necessary precision and relevance of content. Operational personnel tend not to have the requisite authoring skills. Procedures and facilities developed under this project will compensate for this lack of authoring experience, and will enable locally qualified operational experts to prepare materials that will meet the needs of OJT.

B. Summary of Project Activities

The first phase of activities of the project was concerned with the development of two model lessons that seemed especially appropriate to technical training in OJT, the target area of application. Procedures to author each of these were developed. The procedure for authors on preparing a Pure Procedure was based on earlier experience in the preparation of materials for the AN/TRC-97A under prior contract with the Air Force Communications Service (AFCS). The other lesson type, TPI (Task Procedure and Interpretation), is a new product developed under this contract and is uniquely suited for delivery of technical training by means of a computer-based system at the work site. These developments were reviewed in the previous Semiannual Technical Summary.*

Operations on-site during the past six months have been managed by a resident Lincoln person, acting as the LTS training coordinator and supporting Air Force technicians in the authoring of lessons. These efforts have proven very productive in the sense that observations of the authoring process led to a major revision of the procedures. The first few authors read through the procedures but tended to ignore them in preparing the lesson; as a result, the products contained much explanatory and little task-related material. Control of the authoring process was

* Semiannual Technical Summary Report on the ARPA Authoring System, Lincoln Laboratory, M.I.T. (31 July 1976), DDC AD-A032341/0.

achieved by dividing the procedure into three steps: preparation of an outline, of a frame flowchart, and of the First Draft in notebook form. The product of each step was reviewed by the training coordinator before proceeding. At first, it was necessary for the training coordinator to participate in the authoring process because of deficiencies in the procedures. As communication with the author improved, the monitoring was reduced to interaction on the product at the completion of each step. (Typically, after the author makes corrections in the Final Draft notebook, the lesson is taken over by the training system and is assigned to other personnel for artwork, logic preparation, etc. Capturing the expertise of the SME (Subject Matter Expert) is complete at this point except for a review and checkout of the final form before commitment to fiche.) Several of the lesson projects were completed, reviewed by peer SMEs, and tried out successfully on novice personnel. None of the completed lessons, however, were prepared under conditions such that a formal test of their effectiveness would constitute a valid test of the authoring procedure. In addition to revision of the authoring procedures, a characterization of the role of the SME as author was developed. It was based on this early experience, as well as on authoring efforts by two Air Force personnel assigned to do their work at Lincoln Laboratory. The result of analysis of the SME's authoring task is presented in Sec. II.

A major revelation was the severe difficulty of conducting material-preparation activities at an operational site. Three facts dominate: (1) an SME who is qualified to author is, by definition, qualified to conduct operations; (2) the supply of qualified personnel is chronically short; and (3) training always has second priority to operational missions. Thus, a number of lessons started by authors in this project were left incomplete because of the reassignment of personnel to more-pressing duties on-site, in the field, and overseas. The usual one-on-one OJT, of course, also suffers under conditions such as these, proof of the need for a better system. It has been suggested as an alternative that the training materials be obtained from an outside source. However, qualification requires task and equipment-related knowledge, in addition to general technical knowledge obtained through recent work experiences. Prior experience may no longer be valid because this kind of factual information is easily forgotten and the facts remembered often rapidly become outdated. There is a risk that training materials prepared by a lesser expert will be partially irrelevant. Much worse, they may actually have an adverse effect on work performance. The only realistic way to introduce automated delivery to OJT in most cases is for managers to dedicate a fraction of truly qualified SME talent to materials preparation in critical areas. This policy will assure that the materials are effective and that all qualified personnel can rely on the materials to relieve them of training duties in the long run. This and other system requirements are reviewed in Sec. II. It also seems essential that the SME work away from the operational setting. Because of the difficulty of conducting uninterrupted authoring activity on-site, two authors were brought to Lincoln Laboratory to obtain examples of a valid authoring process. This effort proved entirely successful; it is described in detail in Sec. III.

The present site, because of the other demands on personnel, is also not satisfactory for conducting extensive tests of lesson products. Test operations have been initiated at the 2nd CCG at Patrick AFB to add to our source of authors and test subjects. Substantial efforts have gone into preparation of hardware and software to support field operations. Two LTS-5 delivery units have been completed, and one delivered to each site. A duplex software system has been developed that continues to support the LTS-3S materials, the AN/TRC-97A Procedures currently in use as familiarization training at both sites. Each unit also supports lessons that

incorporate new features of the LTS-5 that improve the versatility of instructional delivery and permit recording of training data on-site. Computer-based experimental author support facilities have been developed and are in use at Lincoln Laboratory; deployment to the field has not been feasible because of the multiplicity of sites where authoring activity is planned. Moreover, operations such as logic generation and data dumps have been reduced to elementary procedures. Specific needs for this kind of support can readily be specified by the author and executed effectively by support personnel. Authors are given a chance to review and check out their lessons on an LTS unit when they first appear on fiche, and corrected fiche are issued. In view of the scarcity of the SME as a resource, provision of these kinds of support services for authors is probably the efficient way to proceed even in the long run.

II. SYSTEM REQUIREMENTS

As a result of the activities at the field site, both general requirements for OJT and, more specifically, the role of the SME as author have been clarified. The need for efficient use of the SME as author is established, and these findings are summarized briefly here to amplify other system requirements.

A. The OJT System

Training in the OJT environment is carried on as part of the work management system. The overriding consideration is preparation of personnel to perform work; and from the work manager's viewpoint, the only valid criterion for evaluation of training is its effect on work performance.

Although there is an acute need for training, personnel and equipment tend to be dedicated to unit operations other than training. The experience at the 5th CCG reinforces the necessity for short-term and efficient use of SMEs as the source of materials because they are a scarce resource. In this regard, requirements for OJT differ from those for traditional schooling, and the SME as author must be accommodated to achieve a workable system.

Largely as a consequence of the policy of continuous reassignment of personnel, there is a continual influx of novices to receive primary OJT. There are also experienced personnel to be cross-trained who may be handled two ways: (1) by providing broad understanding of equipment and operations in the primary OJT, or (2) by providing additional training on demand. The latter strategy seems the only feasible one because of the increasing diversity of equipments and systems that a technician must deal with in his career. Specifically, there is a need for training materials designed to accommodate both novice and experienced personnel.

OJT must have a direct benefit in terms of improvement of work performance. Rehearsal of specific work procedures, although necessary, is not always sufficient. The level of training must often be rather sophisticated to apply to complex technology. In areas such as maintenance training, there is a need to impart cognitive skills of judgment such as decision-making and problem-solving at moderate levels of complexity. That is, the technician must have an appropriate level of skill knowledge to deal with unforeseen problems.

Another major requirement of the training system is flexibility to adapt to change of circumstances – to both novice and experienced personnel, to new equipment, to new operational doctrine, and to new missions. The need for adaptability rules out developing a large stabilized system for OJT. It seems more profitable to regard training as a branch of the work management system constantly under development. Within the work system, the role of SME as author

is an extension of his role as operator or technician. Specifically, authoring is an alternate means for providing live one-on-one training.

In summary, OJT serves to improve work performance. SMEs must be used extensively in lesson preparation, but are a scarce resource. Trainees have a variety of backgrounds to be accommodated. There is a need for training in cognitive skills beyond memorization of terms and work sequences. And, flexibility to adapt to changing system and work conditions is essential.

B. The SME as Author in OJT

The typical candidate for authoring is an expert within the work system with a repertoire of technical and operational skills. From the work manager's viewpoint, the goal is to use this expertise in a different way, capturing it in training materials for delivery on a computer-based, individualized training unit. The primary duty for authors of this kind is nonetheless to perform work, and the best of them are often a scarce resource. Therefore, they can be assigned to lesson preparation only for brief intervals. To expedite lesson preparation, explicit procedures have been developed. Qualitative observations of authoring by procedure to date indicate that it is a feasible and practical approach.

At first, it is not obvious that the SME can produce materials which impart requisite cognitive skills such as judgment and reasoning. Instruction at this level has long been considered to depend on instructional expertise. In fact, some SMEs are rather unskilled in this regard, as exhibited in their attempts to conduct one-on-one OJT. In the information-test-correction cycle of computer-based instruction, the information is the most difficult part for the SME to provide. In this area, the author is helped by presentation of a few practical rules and suggestions and by examples of displays. The test-and-correction phase on the other hand is seldom difficult for the author to handle. Much of the OJT involves practical judgment which, although at times a bit complicated, is rarely esoteric. In this context, the primary function of a test is not the cognitive one of testing comprehension but a motivational one. If the trainee expects to be tested on every explanation offered, he or she has good reason for getting matters right the first time. The reward is rapid progress through the lesson. Thus, a test need not be elaborate or exhaustive, but merely relevant and sufficiently difficult to make a guessing strategy by the trainee unattractive. This degree of monitoring student progress is similar to that associated with conventional schooling, in contrast for example to the more-intensive diagnostic methods occasionally realized by live tutors and by advanced computer systems.

Another major need is to help the author organize his lesson material. The approach here is to let the SME choose the most appropriate lesson type from among several models, and to provide an authoring procedure for each model. The two designs emphasized to date are the Pure Procedure and the TPI, which are explained below. They are organized around the work experience, either natural or contrived sequences of tasks prototypical of what the trainee is likely to encounter. An advantage of basing lessons on the work sequence is that it is more familiar than other modes of lesson organization such as concepts or principles.

In summary, the need to impart an adequate understanding of equipment and systems does not appear to depend on sophisticated training methods. The goal of OJT is to produce a technician, not an engineer. Organizing lessons around the work process is a "natural" for the author – as well as for the trainee, work manager, and other SMEs. It serves the overall goal of improving work performance by delivering instruction in work procedures in a way that can be generalized to a variety of tasks on a given equipment or system.

III. AUTHORING ACTIVITIES

Two examples of authoring activities are described here. Each was conducted under controlled conditions to establish further the feasibility of the approach.

A. Pure Procedure as Model Lesson

The Pure Procedure presents the step-by-step actions required to execute a job on an actual piece of equipment in sufficient detail for a novice technician to follow. In maintenance, the informational requirements are the same as for the JPA (Job Performance Aid). Displays show explicitly the location of parts, terms are operationally defined, and standards of safety of the trainee and the integrity of the equipment are maintained. The overall goal of Pure Procedure in the computer-based instructional environment differs, however, from the JPA, which is primarily a means to effect equipment repair with unsophisticated technicians.

Following a procedure serves also as a kind of familiarization training. The user learns facts about the equipment and the content of routine maintenance operations. At regular intervals, the work performance is subject to checks. The trainee enters information about results of his operations, such as meter readings, and the instructional terminal compares these with expected values. It branches to remedial actions whenever there is an erroneous result. The purpose of these checks is not only to correct errors by feedback, but, at a broader level, to keep the user constantly accountable for his work. In the LTS-5 delivery unit, his inputs are also recorded on a tape cassette. Both immediate checks and automated logging assure quality of work performance and enhance learning about the equipment and the maintenance process.

Factual material learned in this manner is, of course, transient in memory. Also, it does not provide understanding that allows transfer to new situations, e.g., meeting contingencies not provided for in the procedure. It is highly useful in that it prepares the trainee to do standardized procedures and, after a few repetitions, enables him to do so with the aid of a condensed JPA, a work card. More significantly, it provides a sound basis for a continuation of training in a task-oriented environment. About 12 hr of this kind of material, standard maintenance procedures on the AN/TRC-97A radio set, were prepared by Lincoln Laboratory. These have been in use for 1 year at the 5th Combat Communications Group, the project field site at Robins AFB, Georgia. Novice personnel, roughly 40 in all, who were unfamiliar with this equipment have received their initial training on these Pure Procedural lessons. Formal evidence is lacking, but the maintenance section manager continues to rely on this capability because he feels it enhances work performance and benefits training.

An opportunity for Lincoln personnel to get a closer look at the Pure Procedure authoring process was afforded when SSgt Case of the 2nd CCG was sent to Lincoln on temporary assignment for 2 weeks in February of this year. His mission was to be trained to maintain a new LTS-5 being installed at his home station, and to learn about the software and courseware technology of the machine. As part of his indoctrination, he produced a 1-hr Pure Procedure on X-Y Diode Alignment of the LTS-5. First, he received training on the LTS-5 hardware; then, he converted an abbreviated SOP extant on paper to an illustrated, step-by-step procedure. His effort was monitored closely, and thus served as a test of the lesson for authors on development of this kind of lesson.

Development of a Pure Procedure requires: (1) accurate initial specification of content, (2) step-wise guidance in lesson preparation, (3) review of intermediate lesson products by an

TABLE I

TWO EXAMPLES OF PREPARATION OF LESSON FINAL DRAFT

Lesson Type	Pure Procedure			TPI		
Author	SSgt Case			SrA Robinson		
Title	Alignment of X-Y Diodes...			Voice Circuits of AN/TRC-97A		
Lesson Duration (hr)	1			1		
Number of Frames	23			45		
	Author	Other SME	LTS-5 Training Coordinator	Author	Other SME	LTS-5 Training Coordinator
Preparation Time:						
Initial Specification	0	10	0	25	5	10
Prepare Draft I	18	1	4	40	0	8
Review and Revise	2	1	4	12	5	2

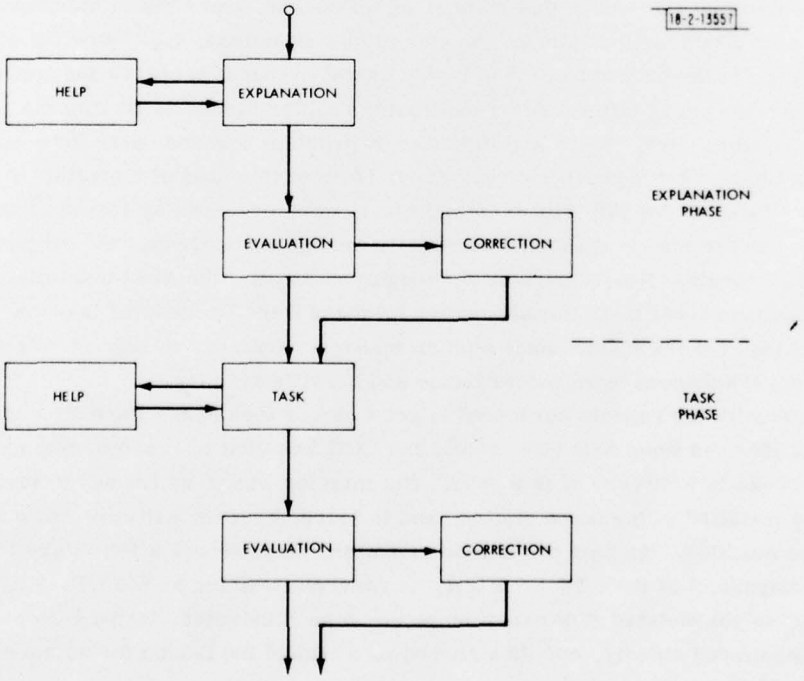

Fig. 1. Flowchart of TPI model lesson.

LTS training expert, and (4) review of content by other SMEs. In this instance, authoring went smoothly and the amounts of time spent in producing an initial draft are shown in Table I. Tests on a few trial subjects uncovered only a few minor flaws in this product. As is often the case in the development of a Pure Procedure, a change of content is a more likely basis for revision than form – a work procedure must be accurate in every detail. SSgt Case was a novice author and was relatively unsophisticated in the content subject matter, LTS-5 hardware technology. Yet the lesson development process functioned well, allowing the author, with assistance from other SMEs and a member of the staff acting as the training coordinator, to produce a final product efficiently.

B. The TPI as a Model Lesson

The other kind of lesson under development is the TPI (Task Procedure and Interpretation). It is a lesson model that has appeared sparingly in the past, perhaps because to be effective it depends heavily on the capability of a computer to monitor progress, and computers have not as yet been very practical for application at the work site. The advent of the LTS-5, combining microprocessor capability with audio/visual displays, makes it reasonable to deliver instruction in this mode for OJT.

The formal structure of a sub-unit of TPI instruction is shown in Fig. 1. There are two sequential phases within a sub-unit; explanation, information about part of a system or equipment; and task, a work instruction supported by the prior explanation. Within each phase, the primary information is supported by optional information, by performance tests, and by remedial information.

In the explanation phase, an option to get Help provides additional detail to assist those trainees that do not fully grasp the Explanation. The presence of a Help option at each step is a means to accommodate both novices and experienced personnel within the same lesson. The Evaluation is a test of learning. It serves (1) as a partial check of the trainee's capability to use the information in solution of a problem, (2) as a timely reminder of the relevance of the concepts, and (3) as an inducement to learn. The Correction attempts to assist the trainee who fails the test; it is keyed when necessary to the kind of error made. When the Evaluation is failed repeatedly, the trainee may be advised to "Go find your instructor."

The task phase is entered after there is a reasonable assurance that the explanation has been mastered. Analogous functions are served in this phase; the trainee is performing a task and selects a course of action consistent with the prior Explanation. Typically, the Help option explains sub-tasks in more detail, such as how to set up a measurement. Evaluation is based on the measurement or other result inserted by the trainee. Correction usually indicates how the outcome was unacceptable in terms of the previous explanation; again, the trainee who fails repeatedly or in a particularly unfortunate manner is directed to obtain assistance. The trainee moves through a sequence of units of this kind that he or she is likely to experience in a typical work situation.

The model of the TPI in Fig. 1 is presented to the SME author as a guide, but is rarely realized in exactly this form. Only the essential blocks are included. Some functions may be elaborated in several frames or even in a sub-unit; inessential form and content are omitted. The task phase may even precede the explanatory phase.

In planning a TPI, the first step is to select a typical work process (experience) or a standard procedure for the lesson model. Characteristically, a TPI serves the purpose of showing

the trainees how component tasks meet system requirements and how various conditions affect the choice of actions. It is sometimes profitable not to require the trainee to carry out operations on real systems, even if otherwise feasible, but to give a simulated work experience free of irrelevant procedural details. One way or another, the TPI is suited for capturing the kind of subject matter expertise, job-related practical judgment, and reasoning capabilities that are essential to the operation and maintenance of complex systems and are particularly difficult and costly to impart in the OJT environment.

C. Example of TPI Preparation

The project operates within the "ISD/LTS-5" training activity of TAC COMM AREA of the Air Force Communications Service. A TPI lesson was prepared on field installation of audio circuits of the AN/TRC-97A. The requirements for this lesson were established by the 5th CCG under a mission to design new training materials, using the principles of ISD (Instructional System Design) as presented in AFM 50-2. It was implemented by SrA Robinson, an SME on temporary assignment to the ISD/LTS-5 team.

At the initiative of the maintenance managers, two areas of training were identified as particularly critical by the Wideband Section of the 5th CCG. Robinson was assigned to develop one of them – the lesson on "handling requests and reports from the Tech Controller by the operation/maintenance technician of the AN/TRC-97A." He first compiled a list of 33 kinds of requests and reports, and listed appropriate actions for each. This product was reviewed by his SME peers and amended. At this point, Robinson was ready to begin to prepare a lesson and was temporarily assigned to Lincoln Laboratory to do the job.

Initial review of the requirements, with a project staff member acting as an LTS-5 training coordinator, centered around the content and goals of the lesson. The lesson is a simulation of a typical operational sequence and assumes that the trainee is familiar with basic techniques of patching and measurement. The topic was narrowed to setting up the voice section of the multiplexer. The procedures involved did not cover all possible situations, but provided an opportunity to explain most of the concepts of the equipment and of operational doctrine required to make a proper working installation of the set. An overall lesson plan was devised that followed a typical scenario in establishing the voice circuits when a TRC-97A is first set up in the field on mobile deployment. Each episode became a sub-unit of instruction within the TPI, as described in the previous section. It is intended to be used with the actual equipment on hand.

The author then proceeded to follow the TPI lesson design procedure through the prescribed stages: preparation of outline, flowchart, and draft frames in notebook form. Each stage was presented to the author by the training coordinator; the author then worked independently, and the product was reviewed and revised before proceeding to the next stage. The final draft notebook was reviewed by two peer SMEs and was run manually on two novices at the 5th CCG. It is being readied on fiche to be tested at the 2nd CCG at Patrick AFB (see Sec. D below).

The author was able to infer principles of lesson design from examples, and to differentiate essential from nonessential information for the target training population. The procedure that underlies the TPI development process seemed to assist the author greatly in orderly development of the lesson, in communication with the training coordinator, and in critical evaluation of his products. However, preparation of any kind of individualized material is a time-consuming task. Times in preparation of a final draft (ready for conversion to film cards) are shown in Table I. The author spent 77 hr, and had 30 hr of the peer and training coordinator support in the preparation of the lesson which will provide about 1 hr of training.

Four problems the technician faces in mobile deployment, that were identified as important in the specifications, were not handled in this particular TPI lesson; so each was dealt with in a second, follow-on lesson made up of four parts. A work problem was presented and carried through several stages to a final resolution. However, the usual explanatory phase ahead of each task phase was eliminated. This lesson was planned as a follow-up since it was judged that the requisite explanatory information was adequately covered in the original TPI. Whenever an improper action was selected, interpretive corrections were given as in Fig. 2. Such a lesson might be called an Exercise Lesson – it resembles the exercises at the end of chapters in text, but goes beyond them in providing remedial information, both conceptual and practical in nature.

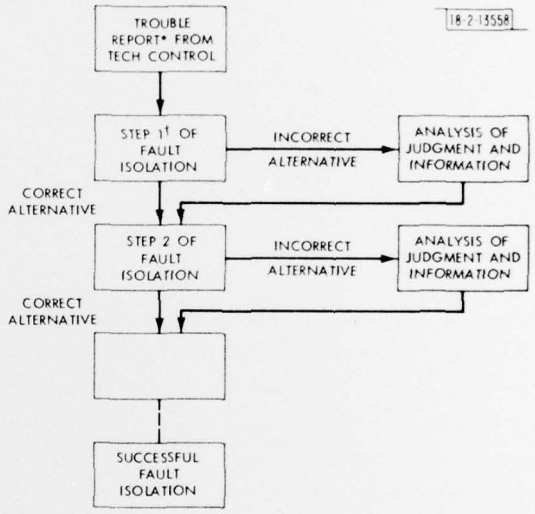

Fig. 2. Flowchart of Exercise Lesson developed for set up of voice circuits for AN/TRC-97A.

*AN EXAMPLE OF A TROUBLE IS THAT TECH CONTROL AT "A" REPORTS THAT "D" IS NOT GETTING HIS TONE ON CHANNEL 6.

†EACH STEP INVOLVES THE IDENTIFICATION OF WHAT TO PROBE IN THE SYSTEM, OR HOW TO PROBE, OR THE EVALUATION OF A RESULT.

An Exercise Lesson may have a number of goals – to test comprehension, to consolidate learning, to cover special cases, and so forth. In brief, the TPI presents the prototypical experience and the Exercise Lesson deals with the exceptional and miscellaneous cases. A number of Exercise Lessons have been developed previously for the LTS in basic electronics, digital systems engineering, and mining technology. Robinson, having already prepared a TPI, required very little additional instruction in the preparation of his Exercise Lesson. In view of this finding, there is little reason to provide a separate procedure for authors to support this design.

D. Test Plans

TAC COMM AREA of AFCS has provided an opportunity to conduct operations at an additional site, the 2nd CCG at Patrick AFB. This Group has manpower, equipment, and other resources available to conduct authoring activities and to evaluate lesson products in formal trials. An LTS-5-based training operation of the AN/TRC-97A has been established at that site, and an

extensive test of the new lesson is planned as an initial effort. This test will involve 10 to 20 novice technicians who have undergone familiarization training on the LTS-5. The lesson will be administered to each individual, and pre- and post-tests of skill knowledge and work performance will be used to measure learning. Each performance test measures the ability to cope with typical problems, as simulated on the LTS. Although it would be preferable to assess the transfer of training to actual work performance in field operations, the feasibility of obtaining "hard" data of this kind is not yet apparent. This test is a prototype of a series of tests to validate the concepts and techniques of the proceduralized approach to authoring by SMEs.

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